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((IMPROVING YIELD, QUALITY AND STORAGEABILITY OF GARLIC (*Allium sativum* L.) BY PRE-HARVEST FOLIAR APPLICATION))

Gmaa, S.S.
Department of Plant Production, Desert Research Center, Matariya, Cairo Egypt,

ABSTRACT

An experiment was conducted at Siwa oasis Research Station, Desert Research Center (Khimisa Farm) during the two consecutive seasons of 2013-2014 and 2014-2015, to evaluate the effect of some foliar spray treatments (Calcium, Potassium, Salicylic acid ,Chitosan, and Menthol) on growth, yield, quality and strogability of garlic.

Results revealed that chitosan, potassium and salicylic acid increased growth characters, yield and its component when compared with calcium, menthol and the control treatments in both seasons. Also, chitosan enhanced calcium, potassium, TSS and L ascorbic acid content at harvest compared with other treatments. During storage period weight loss and decay percent of bulbs were reduced with calcium, chitosan and potassium treatments when compared with other treatments.

Keywords: Garlic, Calcium, Potassium, Chitosan, Salicylic acid, Menthol, Chemical composition, storage potential.

INTRODUCTION

Garlic (*Allium sativum* L.) is a second vital cultivated *Allium species* after onion worldwide. Its widely consumed as a spice form, flavoring and seasoning dishes, pickles and sauces. Popularity of this crop has been increased owing to a lot of health benefits attributed to garlic consumption (Rosen and Tong, 2001).

Salicylic acid naturally occurs in plants in very low amounts. It has been identified as an important signaling element involved in establishing the local and systemic disease resistance response of plants after pathogen attack (Alvarez, 2000), stimulated the growth and oil yield of basil and marjoram by enhancing photosynthesis and nutrient uptake (Gharib, 2006), increased root and shoot fresh weight, number of inflorescences and fruits, fruit nitrogen concentration and yield of strawberry (Jamali *et al.*,2011), increased total leaf area and leaf and shoot dry matter, proline, soluble carbohydrate and fruit weight of strawberry under drought stress (Ghaderi *et al.*, 2015). Many numerous studies have demonstrated that a wide range of responses might appear after exogenous SA application as follows: yield increases (El-Tayeb, 2005; Khodary, 2004; Yildirim *et al.*, 2008), more photosynthetic activity (Singh and Usha, 2003), , inhibiting ethylene biosynthesis (Huang *et al.*, 2004), may be a prerequisite for the synthesis of auxin and/or cytokinin (Metwally *et al*., 2003) and protection against biotic and abiotic stresses (Doares *et al.*, 1995; Karlidag *et al.*, 2009).

Calcium and potassium are the plant nutrient most closely related to fruit quality, and firmness in particular. It involved in plant cell wall integrity and has been reported in its role in improving storage life of several fruits. A shortage of calcium results in less ability to resist the infection by plant pathogen. Low levels of calcium in cell wall also tend to increase the chances of infection and growth of plant pathogens (Matchima, 2013). Preharvest calcium application may be considered as a cultural practice for maintaining adequate calcium concentration in fruit by applied it as supplemental fertilizers in soil amendments or foliar sprays as calcium chloride and calcium nitrate (Naradisorn, 2013). Calcium application increased fruit firmness and reduced severity of anthracnose and brown rot diseases of fruit (Ghani *et al*., 2010), Ca content, fruit firmness, ascorbic acid content and reduced the decay of strawberry fruits during storage at 20°C for 2 days (Naphun *et al*.,1997). Moreover, Ca application delay postharvest softening and decrease weight loss of blueberry fruit (Angeletti *et al*., 2010). Potassium application on garlic significantly increased plant growth, yield and its components and concentration of TSS, N, P, K as well as chemical constituents, storability of bulbs (El-Morsy *et al*., 2004).

Chitosan is derived from chitin, a polysaccharide found in exoskeleton of shellfish such as shrimp, lobster or crabs and cell wall of fungi (Wojdyla, 2001). Recently, some researchers reported that chitosan enhanced plant growth and development (Chibu and Shibayama 2003, Gornik *et al*., 2008 and Said *et al*., 2012). They reported that application of chitosan increased key enzymes activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and improved the transportation of nitrogen in the functional leaves, which is in turn enhance plant growth. Moreover, demand for natural preservatives in foods has increased. Chitosan is a natural antimicrobial biopolymer with a good film forming ability. Hence, it is used as an edible coating on whole and fresh cut fruits and vegetables where, chitosan improves storability of post harvest fruits and vegetables because it forms a semi permeable film that regulates the gas exchange and reduces transpiration and respiration, hence weight loss is reduced and fruit ripening is slowed down. This effect has been reported for numerous horticultural commodities such as tomatoes and strawberries (Bautista *et al*., 2006; Jiang and Li, 2001; Kittur *et al.*, 2001;), radish (Raghuram and Srividya, 2013), garlic (El-Sagan and El Dsouky, 2015;Khreba, *et al*., 2014).

Menthol is a naturally occurring cyclic monoterpene used in oral hygiene products, confectionary, pharmaceuticals, cosmetics, pesticides, and as a flavoring agent (Uzma *et al.*, 2011). It may be

developed at commercial level to protect the pulse grains attack of adzuki bean beetles during storage in homes and market places (Dwijendra, 2001), used for contact and vapour toxicity, and ovicidal and repellent activity against the storage pests *Callosobruchus maculatus, Rhyzopertha dominica, Sitophilus oryzae* and *Tribolium castaneum* (Aggarwal *et al.*, 2001), reduced the sprouting and growth of potato tubers up to 100 days of storage (Ashiv, 2002), improved the beneficial effect of modified atmosphere packing MAP in terms of delaying weight loss and color changes, retarding degrees Brix/acidity ratio evolution, and maintaining of firmness and delayed rates of deterioration and berry decay (Valverde *et al.*, 2005).

All chemical and natural elements such as calcium, potassium, salicylic, chitosan and menthol have been reported to be more effective on growth, yield and delaying fruit deterioration. So, the aim of our work was to investigate the effect of these materials when treated on garlic plants pre harvest.

MATERIALS AND METHODS

Location and experiment design:

An experiment was conducted at Siwa oasis Research Station, Desert Research Center (Khimisa Farm) during two consecutive seasons of 2013 and 2014. The GPS (Global Positioning System) of experimental site is at 29.12_N latitude and 25.29_E longitude with an elevation of 18 meter below the mean seal level. The experimental design was randomized complete block for 6 treatments with 3 replicates. Garlic bulbs (Chinese cultivar) were planted on first of October in rows 1 meter width under drip irrigation system. Every row contains three lines, 10 cm apart between cloves and the plot area was 10.5 meters. The physical and chemical properties of experimental soil are presented in Tables 1, and 2.

Table (1) Physical and chemical analysis of soil experimental site

Depth (cm)	Particle size distribution (%)				Texture class
	Coarse sand	Fine sand	Silt	Clay	
0 - 30	46.8	28.2	15.4	9.6	Sandy loam
30 - 60	50.0	25.9	18.0	6.1	

Table (1) continue:

Depth (cm)	PH	EC (dS/m)	O.M %	Saturation soluble extract							
				Soluble anions (meq/L)				Soluble cations (meq/L)			
				Co_3^{--}	HCO_3^-	SO_4^{--}	Cl^-	Ca^{++}	Mg^{++}	Na^+	K^+
0 - 30	7.4	2.3	-	-	4.3	1.4	3.7	4.4	1.3	2.9	0.3
30 - 60	7.8	3.7	-	-	4.9	1.5	2.4	4.8	1.8	2.3	0.4

Treatments:

Spraying of the five compounds (Calcium, Potassium, Chitosan, Salicylic acid and Menthol) were done monthly until harvest by (500, 400, 2500, 100, 2000 ppm) compounds, respectively and the same amount of distilled water was sprayed to the control treatment. Chelated calcium 12% (Agrico Co.) and potassium oxide (Huper, Arabian Group of Agricultural Service (AGAS),Egypt were used as a source for calcium and potassium, respectively. In both seasons, all cultural practices (irrigation, fertilization, weeding, and pest control) were performed according to the recommendations of the Egyptian Ministry of Agriculture.

Data recorded:

Vegetative growth:

Random sample of 5 plants of each experimental plot were taken at 90 days after planting for vegetative growth data. Plant height, leaves number/plant, and plant fresh and dry weight were recorded, and then dry matter percent was calculated. A portable chlorophyll meter (SPAD–502, Konica Minolta Sensing, Inc., Japan) was used to measure leaf greenness of the plants. At 90 days after planting, measurements were taken at four locations on each leaf, two on each side on the youngest fully expanded leaves of randomly selected five plants per plot and then averaged.

Yield parameters and its components:

At harvesting stage (180 days from planting date) a sample of 20 garlic plants randomly taken from each experimental plot for yield characteristics, i.e., neck and bulb diameter, average bulb fresh weight and total yield (kg/plot). When 50% of leaves pended and turned to yellowish green color, the plants were collected for each replicate and every 30 plants tie together, tied garlic put on one layer in place must has aeration, but not expose to sun and let 15 days for curing.

Chemical composition:

Three samples of garlic bulb from each experimental plot were taken and oven dried at 70ºC until stable weight then grinded to fine particles and used to determine chemical content. Potassium and Calcium percentage were measured using flame photometer method as described by Brown and Lilliland (1964).Total soluble solids (TSS) were determined for cloves using a JK-SR-113ATC digital Refractometer (Shanghi Co. Ld., China) at 20°C. L ascorbic acid content was determined according to the methods described by A.O.A.C. (2005).

Storage potential :

After the second season, garlic plants were selected from uniformity in size and number from each of replicate, selected plants were cleaned and stored in net bags at room temperature with aeration conditions and shadow for 6 months. After three and six months examination was carried out to calculate the percentage of loss in weight, decay and T.S.S and L. ascorbic acid were determined.

Statistical analysis:

Data were subjected to statistical analysis by M-STAT C (Russel, 1991). The differences among means were performed using least significant difference (LSD) at 5% level according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative growth:

As shown in Table 2, plant height, leaf numbers, plant fresh weight and total chlorophyll content of garlic was significantly affected by foliar spray treatments in both seasons. Potassium treatment gave the highest values of plant height, leaves number followed by chitosan and salicylic acid treatments compared with calcium, menthol and the control in both seasons. Moreover chitosan, potassium and salicylic acid treatments gave the heaviest plants compared with other treatments, while total leaf chlorophyll content was significantly increased by chitosan and potassium treatments compared with other treatments especially the control treatment which gave the lowest value in this respect. Similar results were found by Chibu and Shibayama (2003), El-Morsy *et al*. (2004), Gharib (2006), Gornik *et al*.(2008) and Said *et al*.(2012).

Table (2) Effect of foliar spray treatments on plant height, leaf number, plant fresh weight and leaves chlorophyll content in 2013-2014 and 2014-2015.

Characters	Plant height (cm)		No. Leaf		Plant fresh weight (g)		Total Chlorophyll (SPAD unit)	
Seasons	2014	2015	2014	2015	2014	2015	2014	2015
Calcium	48.81	50.60	9.93	9.81	196.91	199.01	78.40	79.73
Potassium	54.96	56.29	10.67	10.69	216.16	220.49	83.30	84.92
Salicylic Acid	50.17	50.17	10.11	10.24	218.79	223.12	78.18	80.14
Chitosan	50.47	52.21	10.53	10.58	221.78	226.09	83.47	85.01
Menthol	47.85	48.22	9.68	9.76	198.64	203.98	78.41	79.44
Control	47.05	45.38	9.89	9.45	198.36	207.13	76.20	78.45
L.S.D at 0.05	2.28	1.90	0.26	0.16	8.88	8.62	1.66	1.89

Yield and its component:

As shown in Table 3 garlic yield and its components (average bulb weight, bulb and neck diameter) were significantly affected by foliar spray treatments in both seasons. Chitosan and potassium treatments gave the highest garlic yield, followed by salicylic acid treatment compared with menthol, calcium and the control treatments which produced the lowest yield in both seasons. Regarding average bulb weight chitosan treatment produced the heaviest garlic bulb compared with other treatments, followed by potassium then salicylic acid as compared with menthol, calcium and the control treatments. Moreover, bulb and neck diameter were significantly increased by chitosan treatment as compared with other treatments, followed by potassium then salicylic acid treatments. While the control treatment produced the lowest garlic bulb and neck diameters in both seasons. The increment in yield and its component due to chitosan application are reported by Chibu and Shibayama (2003), Gornik *et al*. (2008) and Said *et al*.(2012). They reported that application of chitosan increased key enzymes activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and improved the transportation of nitrogen in the functional leaves, which is in turn, enhance plant growth and yield. Also, El-Morsy *et al*. (2004) reported that potassium application on garlic significantly increased plant growth, yield and its components and concentration of TSS, N, P, K as well as chemical constituents and storability of bulbs. Yield increment due to salicylic acid application were found on strawberry (Jamali *et al*.,2011; Ghaderi *et al*., 2015).

Table (3) Effect of foliar spray treatments on yield, average head weight, head iameter and neck diameter in 2013-2014 and 2014-2015.

Characters	Yield (ton/fed.)		Average head weight (g)		Head diameter (cm)		Neck diameter (cm)	
Seasons	2014	2015	2014	2015	2014	2015	2014	2015
Calcium	8.399	11.811	68.92	88.44	6.13	6.10	1.10	1.24
Potassium	12.131	14.020	92.97	107.93	6.54	6.90	1.25	1.39
Salicylic Acid	7.980	11.567	85.94	94.90	6.44	6.62	1.15	1.29
Chitosan	13.476	14.888	106.96	109.47	6.86	7.02	1.38	1.52
Menthol	9.170	10.749	79.44	85.31	6.31	5.81	1.13	1.27
Control	7.385	10.563	68.61	83.83	5.76	5.71	0.95	1.09
L.S.D at 0.05	1.709	0.916	5.34	3.93	0.21	0.40	0.07	0.07

Chemical composition:

Foliar spray treatments had a significant effect on calcium, potassium, TSS and L ascorbic acid content in both seasons Table 4. Calcium and potassium percent significantly increased in garlic bulbs with calcium and potassium treatments as compared with other treatments in both seasons respectively. Chitosan treatment gave the highest values of calcium and potassium percent after calcium and potassium foliar spray treatments in both seasons respectively, while menthol, salicylic acid and the control treatments gave the lowest values of calcium and potassium content. On the other hand, menthol and chitosan gave the highest values of TSS and L ascorbic acid content compared with other treatments especially, calcium and potassium treatments in both seasons. Preharvest calcium application may be considered as a cultural practice for maintaining adequate calcium concentration in fruit by applied it as supplemental fertilizers in soil amendments or foliar sprays (Naradisorn, 2013). Calcium and potassium application increased fruit firmness (Ghani, *et al*., 2010) Calcium and potassium content, fruit firmness, Naphun, *et al*.(1997) and El-Morsy *et al*. (2004).

Table (4) Effect of foliar spray treatments on calcium, potassium, TSS and L ascorbic acid content in 2013-2014 and 2014-2015.

Characters	Calcium (%)		Potassium (%)		TSS (%)		L. ascorbic content (mg/100g F.W.)	
Seasons	2014	2015	2014	2015	2014	2015	2014	2015
Calcium	1.37	1.34	1.35	1.47	28.53	29.77	25.30	26.30
Potassium	1.23	1.24	1.62	1.67	27.63	28.00	29.33	27.93
Salicylic Acid	1.17	1.17	1.33	1.42	29.60	30.10	28.37	27.00
Chitosan	1.31	1.28	1.47	1.62	32.23	33.30	30.93	31.57
Menthol	1.22	1.19	1.33	1.44	32.17	34.00	32.30	31.23
Control	1.19	1.18	1.34	1.43	31.40	31.00	30.60	30.50
L.S.D at 0.05	0.04	0.04	0.03	0.06	1.73	0.95	1.30	1.41

Storage potential:

Data presented in Table 5 show percent of weight loss, decay, T.S.S and L ascorbic acid at 3 and 6 months during storage as affected with the investigated factors .The lowest values in percent of loss in weight and decay were recorded with calcium when compared with other treatments after 3 and 6 months, followed by chitosan and menthol treatments for weight loss and decay percent respectively. While, salicylic acid, menthol and the control gave the highest value of weight loss and decay after 3 and 6 months. Menthol treatment produced the lowest TSS content of garlic bulbs after 6 months compared with other treatments, while the effect of all foliar spray treatments on the same character after 3 months was not significant. Also, menthol gave the lowest value of L ascorbic acid followed by salicylic acid and control treatments as compared with calcium, potassium and chitosan treatments which gave the highest values in this respect after 3 and 6 months during storage period.

Chitosan is used as an edible coating on whole and fresh cut fruits and vegetables where, chitosan improves storability of post harvest fruits and vegetables because it forms a semi permeable film that regulates the gas exchange and reduces transpiration and respiration, hence water loss is reduced and fruit ripening is slowed down. This effect has been reported for numerous horticultural commodities such as tomatoes and strawberries (Jiang and Li, 2001; Kittur *et al*., 2001 and Bautista-Baños *et al*., 2006), radish (Raghuram and Srividya. 2013), garlic (Khreba, *et al*., 2014 ; El-Sagan and El Dsouky, 2015). Also, Calcium treatment may be improved storability of post harvest vegetables, hence, calcium involved in plant cell wall integrity and has been reported in its role in improving storage life of several fruits and increased fruit firmness (Ghani *et al*., 2010), reduced the decay of strawberry fruits during storage at 20°C for 2 days (Naphun, *et al*.,1997) delay postharvest softening and decrease weight loss of blueberry fruit (Angeletti, *et al*., 2010;). Similar results on garlic treated with potassium were obtained by (El-Morsy *et al*., 2004).

Table 5 Effect of foliar spray treatments on weight loss %, decay %, TSS and L ascorbic acid content after 3 and 6 months during storage.

Characters	Weight loss %		Decay %		TSS		L. ascorbic acid	
Seasons	3 Month.	6 Month.	3 Month.	6 Month.	3 Month.	6 Month.	3 Month.	6 Month.
Calcium	19.00	39.33	12.67	18.40	37.70	47.70	29.60	32.97
Potassium	23.67	40.33	16.67	24.33	37.93	48.63	28.47	32.48
Salicylic Acid	25.67	58.00	18.67	28.17	38.70	48.30	24.33	27.77
Chitosan	21.00	40.33	17.33	27.73	40.80	48.57	29.27	30.73
Menthol	26.00	41.33	16.00	20.87	41.23	45.83	23.67	27.33
Control	25.00	42.00	20.00	32.50	39.57	48.67	24.90	28.60
L.S.D at 0.05	1.43	1.64	1.53	2.25	NS	1.38	1.00	1.10

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((تحسين المحصول والجودة والقدرة التخزينية للثوم باستخدام الرش الورقى قبل الحصاد))

سيد سعد جمعة

قسم الانتاج النباتى – مركزبحوث الصحراء – المطرية – القاهرة – مصر

أجريت هذه التجربة بمحطة بحوث واحة سيوة ، مركزبحوث الصحراء (مزرعة خميسة) خلال الموسمين المتعاقبين ٢٠١٣-٢٠١٤ ، ٢٠١٤-٢٠١٥ لدراسة تأثير بعض معاملات الرش الورقى (الكالسيوم ، البوتاسيوم، حامض الساليسليك ، الشيتوسان ، زيت النعناع) على النمو والمحصول والتركيب الكيماوى والقدرة التخزينية للثوم.

وقد اظهرت النتائج أن المعاملة بالشيتوسان والبوتاسيوم وحامض الساليسليك أدت الى زيادة فى صفات النمو الخضرى وكذلك المحصول ومكوناته مقارنة بمعاملات الكالسيوم وزيت النعناع والمقارنة فى كلى الموسمين. وقد وجد أيضا أن الشيتوسان قد زاد من محتوى الرؤوس من الكالسيوم والبوتاسيوم والمواد الصلبة الذائبة وحامض الأسكوربيك عند الحصاد وذلك مقارنة بالمعاملات الأخرى.و خلال فترة التخزين فان نسبة الفقد فى الوزن وكذلك الرؤوس التالفة قد انخفضت مع المعاملة بالكالسيوم أو الشيتوسان أو البوتاسيوم عند مقارنتها بالمعاملات الأخرى. ويمكن ان نوصى من خلال هذه النتائج أن استخدام الشيتوسان رشا على النباتات قبل الحصاد واثناء موسم النمو يعمل على زيادة المحصول وكذلك اطاة فترة تخزين الثوم تحت ظروف التخزين العادية.